Quality of apple-whey and apple beverages over 12-month storage period

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Summary
Whey-based apple beverages may provide an interesting alternative to other beverage products available on the market but stability of those products has not been established. The present work provides a qualitative comparison of apple and apple-whey beverages over a 12-month storage period. The beverages contained 12% of extract, of which 50% was apple concentrate, and apple-whey beverages contained acid whey. The levels of dry matter, extract, ash, protein and total acidity did not change during the storage period. There were decreases of between 6% and 93% in the concentration of saccharose, lactose, polyphenols and vitamin C, as well as in antioxidant activity and selected colour parameters. There were significant differences between apple and apple-whey beverages in their sensory assessment, both in the 5-point scale analysis and in descriptive flavour analysis. The sensory qualities of beverages decreased significantly during the storage period.

Keywords
apple; whey; beverages; antioxidants; vitamins; sensory analysis

Regular consumption of beverages around the world makes them an important part of the daily human diet [1]. Therefore, beverages should do more than just quench thirst: they should also contain bioactive ingredients beneficial for human health [2]. Beverage consumption all over the world is constantly rising, as is consumer interest in beverages with high nutritional and biological value [3].

Apple juices and beverages based on it belong to the most widely consumed drinks globally due to their favourable sensory qualities [4]. Research has shown that constituents of these beverages are characterized by high bio-accessibility and health-giving properties [5]. The high biological value is primarily due to the presence of polyphenols such as chlorogenic acid, *p*-coumaryloquinic acid and flavonoids [6–10]. In recent years, efforts were made to improve the health-promoting properties of the juices and beverages in question by selecting processing parameters that would increase the concentration of polyphenols or dietary fibre. To this end, cloudy juices and juices with added shredded fruit pulp were produced, while clear juices were added special fining agents that do not precipitate polyphenols [8, 9]. Whey-based apple beverages may provide an interesting alternative to other products available on the market [11]. In previous attempts to produce apple-whey beverages, qualitative features and changes in those features were not precisely determined [11, 12]. However, it is clear that such beverages will not only exhibit the beneficial features of whey, such as high contents of proteins, vitamin B and mineral salts, including calcium and potassium, but also those of apple juice, notably the presence of biologically active substances [5, 7, 8, 11, 13].

The aim of this work was to compare the qualitative changes in apple and apple-whey beverages over a 12-month storage period by examining selected physicochemical parameters such as antioxidant activity, concentration of selected vitamins, colour and sensory properties.

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MATERIALS AND METHODS

Beverage samples

The study material consisted of apple and apple-whey beverages prepared in a laboratory at the University of Agriculture in Krakow, Poland. The beverages were produced using mineral water from the sw. Jana source in Ciecina, Poland; apple juice concentrate from the Tymbark plant (Wadowice, Poland); acid whey, obtained during the production of curd cheese in the OSM Miechów plant (Miechów, Poland); sugar; and citric acid. It was decided that the beverages would contain 12% ± 0.2% extract, of which 50% would be apple concentrate. The acidity balance was adjusted in line with the assumption that total acidity would be 6.3 g ± 0.2 g of malic acid per litre, which required the addition of 2.8 g and 1.2 g of citric acid per litre of apple and apple-whey beverages, respectively. Acidity was adjusted with citric acid (not malic acid) since it is the only acid permissible for beverages by local law [14]. In whey beverages, 50% of water was substituted with whey. After blending the ingredients in one vessel, beverages were pasteurized at 80 °C for 2 min, following which they were filtered and poured into glass bottles (0.33 l) while still hot. The bottles were then sealed and further pasteurized at 80 °C for 15 min. Finally, the beverages were stored at a temperature of 4 °C until analysis. For each type of beverage, 15 bottles were produced. All analyses were conducted on the beverages directly after production (for practical reasons, this was 3 weeks after production), and after 6 and 12 months of cool storage. The testing was conducted in three series of two replications ($n = 6$).

Composition of beverages

The concentrations of dry matter, extract, ash and proteins were determined by the AOAC methods (No. 930.04; 920.57; 978.04; 920.05, respectively) [15]. Total acidity was determined by titration according to the AOAC method 925.53 [15] and expressed in grams of malic acid per litre of product. Glucose concentration was determined by enzymatic colorimetric oxidase assay; the absorbance was read at a wavelength of 500 nm according to YUEN and MCNEILL [16]. Fructose concentration was assessed according to HOFER and JENEWEIN [17] by an enzymatic method with spectrophotometric determination at a wavelength of 340 nm. Saccharose concentration was determined following the enzymatic assay of HOLMES with invertase–catalysed hydrolysis of saccharose and fructose dehydrogenaze–catalysed oxidation of liberated fructose followed by spectrometric determination of fructose with tertrazolium salt at a wavelength of 570 nm [18]. Lactose concentration was assessed according to SHAPIRO et al. [19] by an enzymatic method using thio-nicotinamide adenine dinucleotide as an oxidizing agent with spectrophotometric determination at a wavelength of 405 nm. All spectrophotometric measurements were carried out on Hitachi UV-VIS spectrophotometer type U-2900 (Hitachi, Tokyo, Japan).

Antioxidant activity and polyphenols

Antioxidant activity against DPPH radical (1,1-diphenyl-2-picrylhydrazyl) and cation radical ABTS (2,2-azino-bis[3-ethylbenzthiazoline-6-sulphonic acid]) was assessed by the methods described by PEKKARINEN et al. [20] and RE et al. [21] in extracts prepared with the solvent 80% methanol acidified with 0.5% HCl. Measurement of absorbance was conducted at a wavelength of 516 nm for free DPPH radical and 734 nm for ABTS cation radical over a time of 0 min and 10 min. The value of antioxidant activity was expressed as millimoles of Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid; a water-soluble analogue of α-tocopherol) per litre of the beverage.

Total polyphenol concentration was determined according to the method with Folin-Ciocalteu reagent [22] in extracts prepared with the solvent 80% methanol acidified with 0.5% HCl. Measurement of absorbance was conducted 60 min after the addition of the Folin-Ciocalteu reagent at a wavelength of 675 nm. Polyphenols were expressed as milligrams (+)-catechin per litre of the beverage. All spectrophotometric measurements were carried out on Hitachi U-2900.

Water soluble vitamins

Vitamin C, B_1 and B_2 concentrations were determined by HPLC methods EN 14130:2003 [23], EN 14122:2003 [24] and EN 14152:2003 [25], respectively. For L-ascorbic acid estimation, beverages were diluted with 0.1 mol·l^{-1} phosphoric acid and centrifuged. The analysis was carried out in a liquid chromatograph D-7000 (Hitachi Merck, Tokyo, Japan) with UV-VIS detector (L-7420), pump (L-7100) and autosampler (L-7250). Separation was done on a LiChrospher RP-18 column, 100 mm × 4.6 mm (Merck, Darmstadt, Germany). The elution was carried out using 0.1 mol·l^{-1} phosphoric acid, the flow rate was 1 ml·min^{-1}. The absorbance was monitored at 254 nm. The sum of L-ascorbic acid and L-dehydroascorbic acid was determined after reduction with L-cysteine according to EN 14130:2003 [23]. Samples were mixed with L-cysteine solution and

their pH level was adjusted to 7.0–7.2 using 20% sodium phosphate. Subsequently, samples were stirred for 5 min and their pH level was conversed to 2.5–2.8 with 20% metaphosphoric acid. Solutions were centrifuged and purified using solid phase extraction (J.T.Baker, Phillipsburg, New Jersey, USA) with C18 column (Macherey-Nagel, Düren, Germany). Thiamine and riboflavin were detected using a liquid chromatograph D-7000 with fluorescence detector (L-7480). Analysis was carried out on an Onyx Monolithic C 18 column 100 mm × 4.6 mm (Phenomenex, Torrance, California, USA), and was conducted at wavelengths of excitation and emission: 366 nm/435 nm for thiamine and 370 nm/520 nm for riboflavin. Water and acetonitrile were used as a mobile phase in gradient elution starting with water to acetonitrile ratio 88:12 at $t = 0$ min and ending with water to acetonitrile ratio 0:100 at $t = 12$ min. Flow rate was 1 ml·min^{-1}.

Instrumental colour analysis

Colour measurement was conducted instrumentally according to the CIE system [26] using a Minolta CM-3500d (Minolta, Osaka, Japan). Based on the measurement, the following parameters were established: L^* – colour brightness ($L^* = 0$ black, $L^* = 100$ white); a^* – green colour ($a^* < 0$), or red colour ($a^* > 0$); b^* – blue colour ($b^* < 0$), or yellow colour ($b^* > 0$); C^* – colour saturation; and h^* – hue angle.

Sensory analysis

Sensory analysis was conducted according to PN-ISO 6658 [27] using a 5-point scale (5 – excellent, 4 – very good, 3 – good, 2 – bad, 1 – very bad) by a panel of 15 assessors, all of whom fulfilled the basic requirements as to sensory sensitivity according to PN-ISO 3972 [28]. The basic quality descriptors were taken into account: appearance (colour, sediments and suspension); odour desirability; odour intensity; and flavour. The descriptor of total sensory analysis for the products was established by using the importance factor for individual quality descriptors. The overall result was established by dividing the total points (the product of the marks for particular characteristics and their importance factors) for a given product by the sum of the importance factors.

Descriptive flavour analysis was conducted by a team of 18 people, all of whom fulfilled the basic requirements as to sensory sensitivity according to PN-ISO 3972 [28] and consumed apple beverages regularly. The discussion was moderated by a person with considerable experience of using this method of food quality assessment and highly experienced in the field of fruit beverages and juices. The analysis took into account the following flavour descriptors: sour taste; sweet taste; apple flavour; refreshing flavour, tart flavour, whey flavour, bland flavour, apple odour, whey odour and total flavour assessment. The intensity of individual descriptors was rated on a scale of 0 to 5.

Statistical analysis

The results of the investigation were analysed statistically using two-way analysis of variance (ANOVA) based on the Duncan test with $\alpha = 0.05$. Linear correlation between the antioxidant activity, and the concentration of vitamin C and polyphenols was also established. The Statistica 8.0 programme (StatSoft, Tulsa, Oklahoma, USA) was used for statistical calculations.

RESULTS AND DISCUSSION

Composition of beverages

The chemical composition, particularly saccharides and acids, determines the sensory qualities and nutritional value of apple products [29]. The level of extract found in the apple and apple-whey beverages was in accordance with the presumed level (Tab. 1). The dry matter concentration exceeded the extract concentration by 6.8–9.1 g·l^{-1}. Apple juices available on the Polish market contain 10.2–12.0% refractometric extract [30], while those produced in Turkey usually contain 13.0–15.8% extract [29]. A high level of extract, of about 13.5–14.5%, was also noted by Will et al. [8] in cloudy juices produced in laboratory conditions. Apple beverages contained one third the ash of apple-whey beverages. The ash concentration in apple juices produced from different kinds of apples was twice that found in the apple beverages analysed in the present study [8]; however, with an apple concentrate level of 50% in the beverage extract, the findings are comparable. The addition of whey, which contained 6 g mineral salts per litre, resulted in a significantly higher ash concentration in apple-whey beverages. Whey is a good source of ash, whose main components are calcium, phosphorous and potassium [13]. Another consequence of adding whey was a higher protein concentration in apple-whey beverages than in apple beverages. The period of storage was found to have no effect on the concentration of dry matter, ash and protein.

The presence of organic acids is an important quality indicator of apple juices [5, 31]. The total acidity of apple and apple-whey beverages amounted to 6.2–6.5 g malic acid per litre; this was

Tab. 1. Composition of apple and apple-whey beverages.

Parameter	Type of beverage	Period of storage (months)		
		0	6	12
Dry matter [g·l^{-1}]	Apple	128.7 ± 1.1	128.5 ± 1.0	130.1 ± 1.3
	Apple-whey	128.2 ± 0.9	12.94 ± 0.7	128.8 ± 1.2
Extract [%]	Apple	121.0 ± 1.7	121.1 ± 1.5	121.0 ± 1.6
	Apple-whey	121.3 ± 1.2	121.2 ± 1.0	121.4 ± 1.2
Ash [g·l^{-1}]	Apple	1.5 ± 0.5*	1.5 ± 1.2*	1.5 ± 0.7*
	Apple-whey	5.3 ± 0.4**	5.3 ± 0.3**	5.3 ± 0.5**
Proteins [g·l^{-1}]	Apple	0.7 ± 0.1*	0.8 ± 0.1*	0.8 ± 0.1*
	Apple-whey	3.0 ± 0.1**	2.9 ± 0.1**	3.0 ± 0.1**
Titrable acidity [g·l^{-1}]	Apple	6.3 ± 0.2	6.4 ± 0.2	6.4 ± 0.3
	Apple-whey	6.4 ± 0.1	6.5 ± 0.1	6.2 ± 0.2
Glucose [g·l^{-1}]	Apple	14.2 ± 0.6^{a*}	18.0 ± 1.1^{b*}	23.6 ± 1.7^{c*}
	Apple-whey	12.8 ± 1.0^{a**}	16.4 ± 0.7^{b**}	19.7 ± 1.0^{c**}
Fructose [g·l^{-1}]	Apple	35.9 ± 1.2^{a*}	41.4 ± 0.8^{b*}	45.7 ± 0.5^{c*}
	Apple-whey	33.7 ± 0.9^{a**}	36.1 ± 0.7^{b**}	41.2 ± 1.1^{c**}
Saccharose [g·l^{-1}]	Apple	61.5 ± 1.5^{a*}	54.8 ± 1.2^{b*}	50.6 ± 1.1^{c*}
	Apple-whey	38.0 ± 0.3^{a**}	37.0 ± 1.0^{b**}	35.8 ± 0.8^{c**}
Lactose [g·l^{-1}]	Apple	0.0 ± 0.0*	0.0 ± 0.0	0.0 ± 0.0
	Apple-whey	18.7 ± 0.4^{a**}	16.8 ± 0.7^{b**}	15.4 ± 0.8^{c**}

Values are expressed as mean value ± standard deviation. Titratable acidity is expressed as malic acid.
a, b, c – statistically significant differences between the samples depending on storage time. *, ** – statistically significant differences between the samples depending on the type of beverage.

3.6–4.7 g·l^{-1} less than the total acidity of cloudy juices tested by Will et al. [8] but comparable to that in commercial apple beverages available on the Polish market [30].

The dominant saccharide in the beverages was saccharose, whose concentration was 12.6–25.7 g·l^{-1} higher in apple beverages than in apple-whey beverages. According to Karadeniz and Eksi [29] and Will et al. [7,8], saccharose concentration in apple juices amounted to 15.0–35.0 g·l^{-1}. The higher saccharose concentration in beverages tested in the present study was due to adding saccharose as one of the components of the extract. During the storage period, a significant decrease in the saccharose concentration was noted, probably as a result of its hydrolytic transformation. In the case of both apple and apple-whey beverages, the concentration of fructose exceeded that of glucose, the concentration of both monosaccharides being higher in apple beverages than in apple-whey beverages by 2.2–5.3 g·l^{-1} and 1.4–3.9 g·l^{-1} for fructose and glucose, respectively. Karadeniz and Eksi [29] and Will et al. [7,8] found 50.0–81.0 g·l^{-1} of fructose and 18.0–32.0 g·l^{-1} of glucose in apple juices. The levels of these monosaccharides in the beverages tested in the present work before storage was comparable to the data provided by the above authors, taking into account the fact that apple juice constituted 50% of these beverages. During the storage period, a significant increase in glucose and fructose concentration was observed in apple beverages, probably as a result of hydrolytic decomposition of the higher saccharides. Franworth et al. [32] did not observe changes in the saccharide concentration in frozen orange juice during a 9-month storage period. Lactose was present in apple-whey beverages due to the addition of whey (Tab. 1). The level of lactose decreased significantly by 1.9–3.3 g·l^{-1} during storage.

Antioxidant activity, total polyphenols and water-soluble vitamins

Apples, as well as apple juices, are a source of bioactive secondary plant substances, including polyphenols [8]. Being active electron acceptors, polyphenols have strong antioxidant properties [33]. Before storage, the beverages tested in the present work were found to contain 410–440 mg·l^{-1} (+)-catechin (Tab. 2). Gökmen et al. [6], Oszmiański and Wojdyło [9] and Will et al. [8] recorded levels of 100 mg to

1 500 mg polyphenols per litre. The concentration of these compounds was affected by a number of factors, such as cultivation conditions, variety, and the methods of processing the pulp and clarifying the raw juice. Research on the concentration of polyphenol fractions present in apple juice showed that the dominant polyphenols were those derived from cinnamic acid as well as flavanols and quercetin, with a low proportion of flavonols and absence of anthocyanins [5, 7–10]. During the first 6 months of storage, a significant decrease of 64% was observed in polyphenol concentration in both types of beverage. During the remainder of the storage period, no changes were found in the concentration of these compounds. Oszmiański and Wojdyło [9] also observed a decrease in polyphenol concentration in apple juices produced in laboratory during 6 months of cool storage, ranging from 2% to 57%, depending on the polyphenol compound. The above authors observed that degradation of (+)-catechin and proanthocyanidins was greater than that of flavonols and phenolic acids in apple juices. Klimczak et al. [34] recorded losses of 2–4% in polyphenol concentration in orange juices stored at room temperature for a period of 6 months, substantially lower than in beverages generally and in apple juices.

Compared with other fruits, apples are not a rich source of vitamin C, which means it is of minor significance in the antioxidant properties of apples [33, 35]. Before storage, apple beverages contained 131 $mg \cdot l^{-1}$ vitamin C, of which 93% was L-ascorbic acid. Apple-whey beverages contained 11% less vitamin C before storage, although with a comparable concentration of L-ascorbic acid. Apple juices tested by a number of authors were characterized by a very low vitamin C concentration, ranging from 5 $mg \cdot l^{-1}$ to 20 $mg \cdot l^{-1}$ [4, 9, 33]. In comparison, vitamin C concentration of the beverages tested in the present work should be seen as rather high. This may be the result of using L-ascorbic acid for colour stabilization in the production of the apple concentrate used in the production of the tested beverages. Differences in vitamin C concentration in apples can be as much as five-fold, depending on the variety and insolation during cultivation [9, 35]. Vitamin C and L-ascorbic acid concentration decreased by 54–60% during 6 months of storage. Between the 6th and 12th month of storage, there was a further decrease in these compounds of 17–27% and 84–86%, respectively. Oszmiański and Wojdyło [9] observed the complete disappearance of vitamin C in apple juice after 6 months of cool storage. Far smaller changes (20% to 40%) were observed by Kabasakalis et al. [36] and Klimczak et al. [34] in orange juices and lemon beverages during 6 months of cool storage.

Before storage, antioxidant activity against ABTS radical in apple and apple-whey beverages

Tab. 2. Antioxidant activity, polyphenols and water-soluble vitamins in apple and apple-whey beverages.

Parameter	Type of beverage	Period of storage (months)		
		0	6	12
Polyphenols [$mg \cdot l^{-1}$]	Apple	440 ± 30^{a}	161 ± 22^{b}	144 ± 13^{c}
	Apple-whey	410 ± 20^{a}	153 ± 11^{b}	142 ± 3^{c}
L-ascorbic acid [$mg \cdot l^{-1}$]	Apple	$122 \pm 6^{a*}$	$56 \pm 6^{b*}$	9 ± 1^{c}
	Apple-whey	$109 \pm 8^{a**}$	$44 \pm 7^{b**}$	6 ± 2^{c}
Vitamin C [$mg \cdot l^{-1}$]	Apple	$131 \pm 6^{a*}$	$59 \pm 9^{b*}$	43 ± 3^{c}
	Apple-whey	$117 \pm 9^{a**}$	$48 \pm 5^{b**}$	40 ± 7^{c}
Antioxidant activity against ABTS [$mmol \cdot l^{-1}$]	Apple	445 ± 14^{a}	281 ± 8^{b}	165 ± 11^{c}
	Apple-whey	435 ± 26^{a}	296 ± 9^{b}	151 ± 10^{c}
Antioxidant activity against DPPH [$mmol \cdot l^{-1}$]	Apple	6.3 ± 0.2	6.4 ± 0.2	6.4 ± 0.3
	Apple-whey	6.4 ± 0.1	6.5 ± 0.1	6.2 ± 0.2
Vitamin B_1 [$mg \cdot l^{-1}$]	Apple	–	–	$0.03 \pm 0.01^{*}$
	Apple-whey	–	–	$0.18 \pm 0.03^{**}$
Vitamin B_2 [$mg \cdot l^{-1}$]	Apple	–	–	$0.07 \pm 0.01^{*}$
	Apple-whey	–	–	$0.26 \pm 0.02^{**}$

Values are expressed as mean value ± standard deviation. Polyphenols are expressed as (+)-catechin. Antioxidant activity is expressed in Trolox equivalents.
a, b, c – statistically significant differences between the beverages depending on storage time. *, ** – statistically significant differences between the beverages depending on the type of beverage.

was 43.5–44.5 mmol Trolox equivalents (TE) per litre. During the processing of apples into juice, a considerable proportion of compounds with antioxidant properties remains in the pomace, leading to a decrease in antioxidant activity of over 55% compared with raw fruit. Application of new methods for producing apple juices and beverages have resulted in products enriched in pulp, which is a good source of polyphenols [8]. During the storage of beverages, there was a decrease in antioxidant activity against ABTS of 32–37% and 63–65% in the 6th and 12th months, respectively. During the 6-month storage of apple juices, Oszmiański and Wojdyło [9] noted a decrease of 13–22% in antioxidant activity against ABTS; smaller changes were observed in cold-stored juices than in those stored at a temperature of 30 °C.

Antioxidant activity against DPPH radical was comparable in apple and apple-whey beverages. Miller and Rice-Evans [33] and Will et al. [8] showed from 4.8 mmol·l^{-1} to 11.5 mmol·l^{-1} (expressed in TE) in apple juices, this level being comparable to the results presented in this work. Over the first 6 months of storage, a significant decrease of 23–27% was observed in antioxidant capacity against DPPH. Between the 6th and 12th month of storage, there were further decreases of 15–29%. Oszmiański and Wojdyło [9] noted a decrease of 6–10% in activity against DPPH during 6-month storage of apple juice. The greater decrease found in the present work may be the result of a reduction in the level of vitamin C, which, since it was barely present in the juices tested by Oszmiański and Wojdyło [9], did not affect the level of antioxidant activity.

A high positive correlation was observed between the level of antioxidant activity and the concentration of antioxidants. The correlation coefficient (r) between antioxidant activity against ABTS and both total polyphenol concentration and vitamin C concentration was 0.90. A slightly higher correlation coefficient (r = 0.91) was noted when polyphenol concentration was correlated with vitamin C concentration and antioxidant activity against DPPH.

Vitamin B_1 and vitamin B_2 concentrations were assessed after 12 months of storage (Tab. 2). The vitamin B_1 and B_2 concentration in apple beverages was six times and four times lower than in apple-whey beverages, respectively. Apple beverages are not rich in vitamins B_1 and B_2 whereas, in apple-whey beverages, the concentration of vitamin B_1 is similar to that found in cows' milk, although the vitamin B_2 concentration is significantly lower [37].

Instrumental colour analysis

The colour of a beverage is one of the most important factors influencing consumer acceptance [38]. It is a very important parameter in apple juices, as excessively dark or light colour and cloudiness are regarded by consumers as signs of lower quality or deterioration [39]. Significant differences were observed between apple and apple-whey beverages in the values of particular colour parameters; these values were subject to significant change over the 12-month storage period (Tab. 3).

The value of the L^* parameter in apple beverages was less than half that in apple-whey beverages. This parameter also underwent important changes during the storage period. In apple bever-

Tab. 3. Colour analysis of apple and apple–whey beverages.

Parameter	Type of beverage	Period of storage (months)		
		0	6	12
L^*	Apple	$28.7 \pm 0.5^{a*}$	$31.0 \pm 0.5^{b*}$	$34.2 \pm 0.5^{c*}$
	Apple-whey	$74.1 \pm 0.0^{a**}$	$69.0 \pm 0.1^{b**}$	$69.9 \pm 0.1^{c**}$
a^*	Apple	$-2.3 \pm 0.2^{a*}$	$-2.2 \pm 0.0^{b*}$	$-2.1 \pm 0.1^{c*}$
	Apple-whey	$0.8 \pm 0.0^{a**}$	$2.3 \pm 0.1^{b**}$	$2.6 \pm 0.2^{c**}$
b^*	Apple	$3.5 \pm 0.3^{a*}$	$5.2 \pm 0.1^{b*}$	$5.9 \pm 0.1^{c*}$
	Apple-whey	$26.8 \pm 0.0^{a**}$	$28.0 \pm 0.1^{b**}$	$28.9 \pm 0.2^{c**}$
C^*	Apple	$4.2 \pm 0.2^{a*}$	$5.7 \pm 0.1^{b*}$	$6.3 \pm 0.1^{c*}$
	Apple-whey	$26.9 \pm 0.8^{a**}$	$28.1 \pm 0.1^{b**}$	$29.0 \pm 0.1^{c**}$
h^*	Apple	$124.1 \pm 0.6^{a*}$	$113.2 \pm 0.2^{b*}$	$109.9 \pm 0.8^{b*}$
	Apple-whey	$88.4 \pm 0.1^{**}$	$85.2 \pm 0.2^{a*}$	$84.8 \pm 0.2^{b*}$

Values are expressed as mean value ± standard deviation.
a, b, c – statistically significant differences between the beverages depending on storage time. *, ** – statistically significant differences between the beverages depending on the type of beverage.

Tab. 4. Results of 5-point sensory analysis of apple and apple–whey beverages.

Parameter (importance factor)	Type of beverage	Period of storage (months)		
		0	6	12
Appearance – colour (5)	Apple	$5.0 \pm 0.0^{*}$	$5.0 \pm 0.0^{*}$	$5.0 \pm 0.0^{*}$
	Apple-whey	$3.8 \pm 0.4^{a**}$	$3.1 \pm 0.4^{b**}$	$2.7 \pm 0.4^{c**}$
Appearance – sediments and suspention (2)	Apple	$5.0 \pm 0.0^{*}$	$5.0 \pm 0.0^{*}$	$5.0 \pm 0.0^{*}$
	Apple-whey	$4.0 \pm 0.3^{a**}$	$3.2 \pm 0.2^{b**}$	$3.0 \pm 0.4^{c**}$
Odour desirability (2)	Apple	$5.0 \pm 0.1^{a*}$	$4.9 \pm 0.2^{a*}$	$4.7 \pm 0.2^{b*}$
	Apple-whey	$4.6 \pm 0.4^{a**}$	$4.2 \pm 0.3^{b**}$	$3.9 \pm 0.4^{c**}$
Odour intensity (2)	Apple	5.0 ± 0.0^{a}	$4.7 \pm 0.4^{b*}$	4.5 ± 0.3^{c}
	Apple-whey	5.0 ± 0.1^{a}	$4.9 \pm 0.3^{a**}$	4.4 ± 0.4^{b}
Flavour (7)	Apple	5.0 ± 0.0^{a}	4.7 ± 0.4^{b}	$4.3 \pm 0.5^{c*}$
	Apple-whey	4.9 ± 0.4^{a}	4.9 ± 0.2^{a}	$4.0 \pm 0.3^{b**}$
Overall score (20)	Apple	$5.0 \pm 0.0^{a*}$	$4.8 \pm 0.2^{b*}$	$4.6 \pm 0.2^{c*}$
	Apple-whey	$4.3 \pm 0.2^{a**}$	$4.2 \pm 0.2^{b**}$	$3.5 \pm 0.1^{c**}$

Scale – 5-point scale (1 – very bad, 5 – excellent). Values are expressed as mean value ± standard deviation.
a, b, c – statistically significant differences between the beverages depending on storage time. *, ** – statistically significant differences between the beverages depending on the type of beverage.

ages, it increased by 2.3 and by 5.5 units, respectively, by 6th and 12th month of storage. In apple-whey beverages, it decreased by 4.8–5.1 units; however, no significant changes were observed between 6th and 12th month of storage.

The value of the a^* parameter was negative in apple beverages and positive in apple-whey beverages, the differences being 3.1-4.7 units. In apple beverages, no significant changes were observed in the value of the a^* parameter over the 12-month storage period. In apple-whey beverages, however, this parameter increased significantly during the first 6 months of storage (by 1.5 units), with a further increase of 0.3 of a unit during the subsequent 6 months of storage.

Important differences were observed between apple and apple-whey beverages in respect to the value of the b^* parameter. In both types of beverage, a significant increase in the b^* parameter was noted during storage, amounting to 1.7 and 2.4 units in apple beverages, and 1.2 and 3.1 units in apple-whey beverages by the 6th and 12th month of storage, respectively, compared with the values before storage.

The C^* parameter ranged from 4.2 to 6.3 in apple beverages, but decreased significantly during the 12-month storage period. The value of parameter C^* was almost seven times higher in apple-whey beverages than in apple beverages. During the 12-month storage period, a significant increase was observed in the value of parameter C^*.

The value of parameter h^* was 25.1–35.7 units higher in apple beverages than in apple-whey beverages. A significant decrease of 10.9 units was noted in the value of parameter h^* in apple beverages over the first 6 months of storage; however, no further changes were observed during the remaining 6 months of storage. No changes in the value of parameter h^* were noted in apple-whey beverages.

Sensory analysis

The sensory quality of fruit beverages, their colour, odour, flavour and consistency, is one of the basic factors affecting consumer choice [30]. The differences between the results of a 5-point sensory analysis of apple and apple-whey beverages were significant. Apple beverages scored excellent for appearance on account of their intensive straw-green colour and high clarity that did not change during the storage period (Tab. 4). In view of their less intense colour and the cloudiness and sediments caused by the addition of whey, apple-whey beverages scored from less than good to very good. Moreover, the appearance of these beverages deteriorated during the storage period, the scores for colour as well as sediments and suspension being 1.0–1.1 points lower than before storage. Djurić et al. [11] concluded that sedimentation is a natural characteristic of whey beverages and is the result of the presence of whey in the product. It is therefore necessary to determine an acceptable level of sediments and suspension before the sensory evaluation of these types of beverage as this parameter will inevitably differ from that of fruit beverages.

The beverages tested in the present work scored higher for appearance than those available on the market [30]. The above authors rated the colour and clarity of the beverages from 1.26 to 7.96 points and 7.24 to 9.33 points, respectively, with an average of 4.36 and 8.67 points on a 10-point scale.

The beverages tested in the present work were characterized by an intense and desirable odour. However after 12 months of storage, the acceptability and intensity of the odour in apple beverages decreased from excellent to better than very good. The odour intensity of apple-whey beverages before storage was rated as excellent and the odour acceptability as better than very good; both of those parameters decreased over the 12-month storage period by 0.5–0.6 of a point. Djurić et al. [11] noted that the odour intensity and acceptability in apple-whey beverages was 0.75–0.94 of a point on a 2-point scale.

The flavour of apple beverages before storage was rated as excellent but decreased significantly over the storage period. Apple-whey beverages scored high for their flavour (4.9 points) during the first 6 months of storage, decreasing to 4.0 points by the end of the 12-month storage period. The flavour of the apple-whey beverages analysed by Djurić et al. [11] was inferior to that evaluated for the same type of beverage in the present study, scoring at 6 points on a 12-point scale.

The overall evaluation was determined on the basis of the scores for individual quality descriptors. Apple beverages immediately after production scored excellent, but only 4.6 points after 12 months of storage. Apple-whey beverages were rated lower, scoring 4.3 points after production and declining continually throughout the 12-month storage period to end with a final evaluation of better than good Djurić et al. [11] showed that the evaluation of particular descriptors of sensory quality depended on the composition of the beverage, with the type of fruit concentrate, the amount of dry matter, saccharose concentration, and the pH of the beverage being important factors. In an evaluation of apple-, orange- and peach-flavoured whey beverages, they concluded that apple-whey beverages were rated lowest, scoring only 10.27–12.49 points out of 20. However, the beverages tested in the present work achieved much higher scores for individual descriptors of sensory quality, suggesting they have considerable commercial potential.

Analysis of the profile of flavours showed that, in apple beverages, the dominant odour was that of apples (Fig. 1). Its intensity decreased during the storage period from better than very good immediately after production and after 6 months of storage to good after 12 months of storage. Moreover, after the full storage period, a bland odour was detected. In apple-whey beverages, on the other hand, the dominant odour was that of whey, scoring 3.8 points, whereas apple odour and bland odour were less intensive, scoring 1.6–2.1 points (Fig. 2). Odour descriptors did not undergo significant changes over the storage period.

Apple beverages were characterized by intensive apple and refreshing flavours, both of which scored very good (3.4–4.2 points). These flavours were also important in apple-whey beverages, but their intensity was rated at only 2.1–2.8 points. Sweet and sour tastes also had an important impact on the flavour of apple beverages, although they were less intensive than in apple-whey bever-

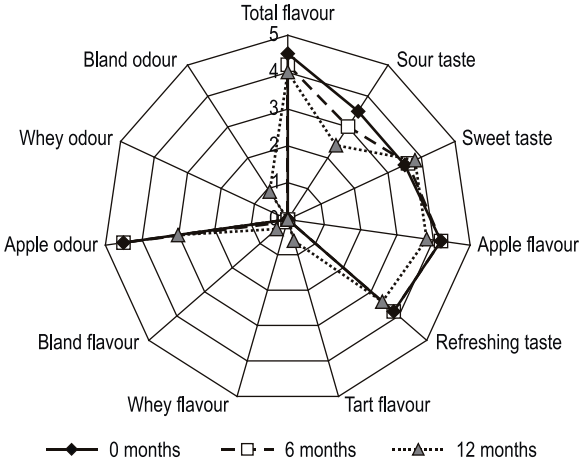

Fig. 1. Representation of flavour profile analysis of apple beverages.

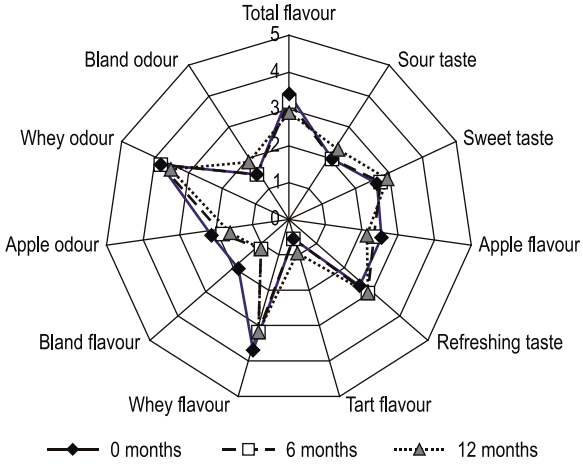

Fig. 2. Representation of flavour profile analysis of apple-whey beverages.

ages. In apple-whey beverages, whey flavour scored good; bland flavour was also present.

The total flavour was a sum of individual components of the flavour profile. Apple beverages scored one point higher than apple-whey beverages. The scores for both types of beverage decreased during storage, by about 0.2–0.3 of a point every 6 months. In the flavour profile analysis, there was a considerable divergence among panel members concerning the values of individual descriptors, resulting in high standard deviation values. This was probably due to the individual preferences of panel members in respect of particular flavour descriptors. It is also possible that panel members compared the taste of the beverages under evaluation to their idea of popular apple juices instead of basing their evaluation on the model value presented by the moderator. In their analysis of juices available on the market, BARYŁKO-PIEKIELNA et al. [30] also observed considerable differences between the scores awarded.

CONCLUSIONS

Compared to apple-whey beverages, apple beverages were characterized by a higher concentration of glucose, fructose, saccharose and vitamin C; they also scored higher in the sensory analysis. Apple-whey beverages, on the other hand, contained lactose, had higher ash and protein concentration, and higher values of *L*, a** and *b** colour parameters. In the sensory profile analysis of apple-whey beverages, the presence of whey and bland odours was noted, neither of which were detected in apple beverages. Saccharose, lactose, total polyphenols and vitamin C concentration as well as antioxidant activity all decreased over the storage period. There was also a significant decrease in the sensory quality of beverages. On the other hand, the colour parameters *L*, a** and *b**, as well as the fructose and glucose concentrations increased during the 12-month storage period. In view of their health-giving properties, the apple and apple-whey beverages tested may constitute attractive products for consumers. Their interesting sensory properties also suggest that they may have considerable commercial potential.

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